PB-242 099

EXPOSURE OF HUMANS TO CARBON MONOXIDE COMBINED WITH INGESTION OF ETHYL ALCOHOL AND THE COMPARISON OF HUMAN PERFORMANCE WHEN EXPOSED FOR VARYING PERIODS OF TIME TO CARBON MONOXIDE

MEDICAL COLLEGE OF WISCONSIN

PREPARED FOR
COORDINATING RESEARCH COUNCIL, INCORPORATED
ENVIRONMENTAL PROTECTION AGENCY

14 AUGUST 1974

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

163120

PB242099

EXPOSURE OF HUMANS TO CARBON MONOXIDE COMBINED WITH INGESTION OF ETHYL ALCOHOL AND THE COMPARISON OF HUMAN PERFORMANCE WHEN EXPOSED FOR VARYING PERIODS OF TIME TO CARBON MONOXIDE

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

AUG 14 1974

Report No.: CRC APRAC CAPM-3-68 MCOW-ENVM-CO-74-2

From the Department of Environmental Medicine, The Medical College of Wisconsin, Milwaukee, Wisconsin 53226

Supported by Contract CRC-APRAC, Project No. CAPM-3-68, From the Coordinating Research Council, Inc., and The Environmental Protection Agency

BIBLIOGRAPHIC DATA SHEET	1. Report No. CRC-APRAC-CAPM-3-68-6	2.	PB 242 099

4. Title and Subtitle

Exposure of Humans to Carbon Monoxide Combined with Ingestion of Ethyl Alcohol and the Comparison of Human Performance When Exposed for Varying Periods of Time to Carbon Monoxide

5. Report Date: August 14, 1974

6.

7. Author(s)

8. Performing Organization Rept. MCOW-ENVM-CO-74-2

9. Performing Organization Name and Address

The Medical College of Wisconsin
8700 West Wisconsin Avenue
Milwaukee, Wisconsin 53226

10. Project/Task/Work Unit No.

11. Contract/Grant No. CRC-CAPM-3-68

12. Sponsoring Organization Name and Address

Coordinating Research Council, Inc., 30 Rockefeller Plaza, New York, N.Y. 10020 and The Environmental Protection Agency, Research Triangle Park, N.C. 27711

13. Type of Report & Period Covered: Final

14.

15. Supplementary Notes

Not releasable to the general public until May 1975

16. Abstracts

The effects of CO and ethyl alcohol on behavioral test performance were assessed at 24 hour exposure as compared to a 5-1/2 hour exposure to identical concentrations of CO. A dose level of 1.6ml of 100 proof alcohol/kg body weight and a COHb blood level of approximately 14 percent were chosen.

The purpose of the study was to test the hypothesis that a 24-hour exposure to low levels of CO would have deleterious effects on behavior and that alcohol would potentiate such effects. The data obtained from tests of coordination, arithmetic, inspection, manual dexterity, time estimation, and vigilance did not provide evidence to substantiate either of these hypotheses. The only positive result was alcohol adversely affects eye-hand coordination.

17. Key Words and Document Analysis. 17a. Descriptors

Carbon Monoxide
Phenacetin
Ethyl Alcohol
Air Pollution

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 06O; 07B; 07C; 13B·

PRICES SUBJECT TO CHANGE

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Releasable to the general public	UNCLASSIFIED	41
	20. Security Class (This Page) UNCLASSIFIED	22. Price $3.75-2.25

FORM NTIS-35 (REV. 3-72)

THIS FORM MAY BE REPRODUCED

USCOMM-DC 14952-P72

The automobile driver who is being exposed to carbon monoxide (CO) while driving home after a social cocktail plus an analgesic to relieve his tension headache is a common figure in our society. Consequently, when trying to assess the potential hazard of CO, the possibility of a synergistic effect with commonly used drugs and ethyl alcohol must be considered. CO exposure along with ingestion of phenacetin or diphenhydramine hydrochloride was the topic of a previous report. This report presents the findings of two sets of experiments, referred to as Study A and Study B designed to assess the effects of CO and ethyl alcohol on behavioral test performance and to assess the effects of a 24-hour exposure as compared to a 5-1/2 hour exposure to identical concentrations of CO.

STUDY A

In the fall of 1970, four experiments were conducted to study the effect of the following agents on man: carbon monoxide, ethyl alcohol, carbon monoxide plus ethyl alcohol and ambient air. Because it was not desirous to have inebriated subjects incapable of performing the tests, a low dose level of 1.6 ml - 100 proof alcohol/kg body weight was chosen. The alcohol experiments were conducted immediately after completion of experiments defining the effect of CO on time perception, reported earlier. Consequently, a CO exposure level of 200 ppm was retained.

METHODS

Protocol

Thirty minutes prior to each exposure the subjects were given an interim physical examination at which time they were questioned about subjective feelings including nausea, headache, dizziness, chest pain, abdominal pain and eye, nose and throat irritation. Pre-exposure blood samples were also obtained at this time for determinations of percent carboxyhemoglobin concentration (COHb).

During the first 150 minutes of each exposure, time tests were performed and correlated with the corresponding COHb saturations. The results of these tests were reported earlier.[1] Between 150 and 195 minutes of exposure time each subject was given 1.6 ml alcohol (Smirnoff's Vodka) per kilogram body weight mixed with orange juice and equally divided between three drinks. The subjects were given 15 minutes to finish each drink. After completion of the drinks, a blood sample was obtained for blood alcohol and % COHb determinations. Immediately following the blood sampling, the behavioral tests were administered over the next 30 minutes and the exposure was terminated at 240 minutes. A post exposure blood sample was then obtained for blood alcohol and % COHb determinations.

Subjects

The subjects were five male and one female sophomore medical students, ranging in age from 22 to 26 years, selected from a larger group of volunteers on the basis of being in good health and because of their expressed willingness to expose themselves to CO. Prior to their selection, subjects were completely informed as to the purpose of the experiments and the potential hazard to themselves. Subjects were paid $1.50 per hour for each hour in the chamber, with a bonus of $1.00 per hour conditional upon satisfactory completion of the study. Baseline % COHb saturations attested that all six subjects were nonsmokers. Prior to and after completion of the study, each subject was given a comprehensive medical examination which included a complete history and physical examination, a 12-lead EKG and an EEG using the standard 10 - 20 electrode configuration.

Exposure Chamber

All CO exposures were carried out in the controlled environment chamber located in the Department of Environmental Medicine, The Medical College of Wisconsin.[1] The environmental system (Carrier) provided accurate control of temperature (72 ± 2°F) and relative humidity (40 ± 5% RH) within the chamber, a room measuring 20 x 20 x 8 feet. The chamber was operated at a slight negative pressure with an air circulation rate of 1,200 cfm. Exhaust and makeup air capacities of 1,000 cfm provided a rapid chamber flushing capability when desired. The chamber featured pleasant lighting,

comfortable chairs, individual testing carrels and a restroom facility. The subjects were under continuous visual surveillance by medical personnel while in the chamber, and in addition, their activities were visually monitored and periodically video taped by closed circuit TV (Sony).

Exposure Chamber Atmosphere

On non-exposure days, outside ambient air was flushed through the chamber. On exposure days, CO was continuously metered into the chamber's environmental system from a compressed gas cylinder in the adjacent command laboratory. Chemically pure CO with a minimum purity of 99.5% was used. The concentration of CO in the chamber atmosphere was continuously recorded from an infrared spectrophotometer (Beckman IR-10) equipped with a 10-meter path-length gas cell which was continuously flushed with air drawn from the chamber through 1/4" diameter polyethylene tubing. An MSA CO Meter and Alarm, Model 701, also independently sampled chamber air to provide a second independent means of continuously monitoring chamber concentration. The chamber atmosphere was also periodically monitored by a gas chromatograph (GC) (Varian Aerograph) equipped with a sequential sampler.

All three methods of monitoring CO concentration during an exposure were calibrated from within the chamber with standards prepared in saran bags.

Analysis of Carboxyhemoglobin Saturation

Five-ml. aliquots of venous blood were collected in Vacutainer tubes containing edetic acid and immediately analyzed for the hemoglobin concentration and the percent carboxyhemoglobin saturation using a CO-Oximeter (Instrumentation Laboratories, Inc.).

Behavioral Tests

The Flanagan Coordination Test (Science Research Associates, Inc., 259 East Erie Street, Chicago, Illinois) measured the subject's ability to rapidly and accurately follow a spiral pathway with a pencil. The subject, while sitting comfortably at a desk in the individual carrel, was allowed 40 seconds to complete each of 6 spirals. The first two were considered practice and the last four were scored and totaled. The score was determined by the distance covered in each spiral minus the number of times the sides of the spiral were touched with the pencil and had a maximum of 100.

The random number inspection test measured the speed with which a subject could detect the number "3" in rows of random numbers on an 8-1/2 x 11 inch page. The subject was asked to inspect each row of numbers beginning at the top of the page and mark as many 3's as possible in two minutes. The subject's score was the total number of 3's struck with an unachievable maximum score of 203. Ten different pages of random numbers were used sequentially to prevent memorization of test answers.

The arithmetic test, which measured the subject's ability to work with numbers, was divided into two parts. The first part, timed at five minutes, consisted of simple addition and subtraction problems while the second part, timed at three minutes, consisted of multiplication and division. The maximum score available, if all answers were correct, was 125; however, no subject completed the test in the allotted time. In order to prevent memorization of answers, ten different tests generated from random number tables were used sequentially.

The Crawford collar-and-pin test, (produced by The Psychological Corp., 304 E. 45th Street, New York, New York 10017) measured a subject's manual dexterity. The test required the subject to use forceps to pick up a pin (0.657" long, 0.063" diameter), place the pin in a hole (0.08" diameter) and place a loosely fitting collar over the pin. The test score was the number of collar and pin combinations placed in three minutes and had a maximum of 42.

Hand Steadiness Test

In the AAA hand steadiness test, a subject passed a hand-held metal wand down through a gradually narrowing V-shaped vertical slot. Contact with either side of the slot completed an electrical circuit which flashed a light. The slot was numerically graduated for recording wand

position, and the score was tabulated by an observer who totaled the results of five trials. The test had a maximum score of 80 and took 1 minute to perform.

Data Analysis

Data analysis of the behavioral test scores used an analysis of variance for two factors. The within treatments mean square was used as the estimate of uncontrolled variability in calculating F ratios.

RESULTS

The blood alcohol levels and COHb saturations determined for each subject at the conclusion of each of the four experiments are presented in Table 1. Subject K. H. (native Chinese) could not tolerate this level of alcohol and was not given any alcohol after the first drink on the first day. His data were not included in the final analysis. The remaining subjects displayed the usual post alcohol ingestion periods of gaiety followed by drowsiness. They remained in good health throughout the study.

Table 2 presents the analysis of variance (AOV) F ratios and their significance. A significant F value appears that CO had an effect on the performance of the collar and pin test. However, this effect was an increase in test score, or an improvement in test performance. The Coordination Test performance was affected by alcohol but not by CO. The test data reveals this effect was a decrease in test performance. Performance of the Arithmetic Test and Hand Steadiness Test were not affected by either alcohol or CO at these levels.

STUDY B

The second series of experiments was conducted in the fall of 1972, and had several distinct differences from the first series: exposure for 24-hours were included, CO exposure was lowered from 200 to 70 ppm and 30 ppm but the steady state % COHb saturation was reached by an initial 30 minutes at 1,200 ppm, and behavioral testing was conducted under the direct supervision of an experimental psychologist. Simultaneous exposure to ethanol and CO was conducted as the last experiment in this series.

METHODS

Protocol

To obtain information on the prolonged effects of CO exposure, four subjects were selected to remain in the chamber overnight for 24 hours, being exposed continuously to CO concentrations of 0, 30, or 70 ppm. A total of six 24-hour sessions were run--three at 0 ppm, one at 30 ppm, and two at 70 ppm.

For the 30 ppm session, there was an initial 20-minute exposure to 1,000 ppm CO, which caused a rapid rise of COHb saturation to approximately 5%. For one of the 70 ppm sessions, an initial 30 minutes at 1,000 ppm caused a rapid rise of COHb saturation to approximately 10%.

CO concentration levels were presented in a random order and every attempt was made to prevent subjects from knowing the CO concentration present during a given session. Questionnaire data obtained at the end of each session confirmed subject's naivete in this regard. The four 24-hour subjects, together with four other subjects who left the chamber overnight, were given behavioral tasks to perform during the first 5 hours and during the last 5 hours of this 24-hour period. A comparison of performance of the 24-hour subjects between the first and the last 5-hour test periods was made to determine the effects of prolonged CO exposure. In addition, all eight subjects were exposed to the three concentrations of CO during regular 5-hour sessions which were scheduled the day before the 24-hour sessions. Four, 5-hour sessions were held, two sessions at 0 ppm, one at 30 ppm, and one at 70 ppm. As with the 24-hour sessions, exposure concentrations were selected randomly for the 5-hour sessions. The purpose of the 5-hour sessions was to obtain additional information on the effects of CO during short exposures.

To determine whether alcohol potentiated the effects of CO, all subjects were studied during two separate 5-hour sessions. These sessions occurred as the final two sessions of the experiment. During the first of these sessions, subjects were given 1.5 ml 100% proof alcohol/kg body weight and exposed to a CO concentration of 70 ppm. During the second

session, which occurred the next day, subjects were given the same amount of alcohol but no CO was present in the chamber. As always, subjects were unaware of actual CO concentrations.

Subjects

The subjects were eight male college students, ranging in age from 20 to 26 years. Of the eight subjects, six were nonsmokers and two were light to moderate smokers who were requested to refrain from smoking for the duration of the study.

Behavioral Tests

Subjects were tested simultaneously while seated at two tables in the environmental chamber. Partitions on the table tops extended several inches beyond the edge of the tables thus reducing visual interaction among subjects and providing a somewhat isolated testing area for each subject. 11 behavioral tests were administered under the direct supervision of an experimental psychologist and were the same as in the first set of experiments (A) except for the deletion of the Crawford Collar and Pin Test and the Hand Steadiness Test, and, the addition of the Time Estimation Tests and a Vigilance Test which are described below.

The vigilance test required subjects to detect and report a complex visual signal presented intermittently over an extended period of time. The test apparatus consisted of eight General Motors readiness-to-drive consoles, one for each subject. During the test, the subject sat facing his console and random four-digit numbers were briefly flashed on a front window of the console after which he pressed the number back into the consol via the console keyboard. Flash duration was 0.7 seconds and the time interval between numbers averaged 18 seconds during a brief, 3-minute alert phase, and 90 seconds during a subsequent 45-minute phase. Subjects remained

at the task for 48 minutes followed by a 12-minute rest period. This procedure continued until 4 hours had elapsed with the beginning and end of each 48-minute session indicated by the offset and onset, respectively, of a light on the console. Over the 4-hour period, 160 four-digit numbers were presented to each subject. The number of four-digit numbers correctly reported within 5 seconds after the number was flashed defined the vigilance performance of a given subject. Subjects reported the numbers by pressing appropriate buttons on the front of the console, labeled 0 to 9, in the same sequence as the number which had been presented. The 5-second period allowed for reporting the number was identified by a white light on the console. Immediate feedback was provided to each subject in the form of a green or red light which flashed briefly at the end of the 5-second interval, depending on whether the number was reported correctly or incorrectly. Unlike the other behavioral measures, subjects were not given extensive training on the vigilance test prior to the experiment because performance on this sort of task which does not test reaction time does not appear to improve with practice. A single 4-hour practice session was conducted to insure that subjects understood the procedure and to familiarize them with the apparatus. During this practice session, and at various times throughout the experiment, subjects were instructed not to talk or interact in any way with other subjects so as to minimize distraction during the test.

The Marquette Time Test consisted of a series of nine tone stimuli followed by a series of nine light stimuli. Each series contained stimuli of approximately 1.0, 1.5, . . . 5.0 sec. duration presented in random order. At termination of each stimulus, the subject depressed a push button switch for that interval of time he estimated to be equal in duration to that of the original auditory or light stimulus. This provided a measure of his ability to estimate the duration of the stimulus; the interval between stimulus termination and onset of the response was a measure of reaction time.

The ten-and thirty-second time estimation tests consisted of each subject depressing the push button described above for an interval equal to that desired (10 or 30 seconds). This was repeated an additional two times for each test.

RESULTS

The blood alcohol levels and % COHb saturations obtained from Study B are presented in Table 3. The subjects displayed the usual post alcohol ingestion periods of gaiety and then drowsiness. They remained in good health throughout the experiment.

Comparison of data obtained from the behavioral testing during the experiments designed to bring the % COHb saturation to a plateau very quickly to that data obtained during experiments where this plateau was reached in a 5 or 8 hour period revealed no significant difference in performance. Therefore, all data from the 30 ppm or 70 ppm exposures were averaged for a comparison of the performance at ' hour of exposure versus 24 hours of exposure.

Coordination Test

Figure 1 presents performances of the four 24-hour subjects and 1 and 20 hour of exposure to 0, 30 and 70 ppm of CO. Comparisons of performances during the 1st and 20th hour indicates the degree to which subjects were affected by CO after prolonged exposure. It is apparent that there were no consistent changes in coordination for subjects exposed to 0 or 30 ppm CO for 20 hours. While all four subjects showed slight improvements in coordination performance after 20 hours of exposure to 70 ppm, the small magnitude of the mean difference and the large amount of variability, as expressed by the standard errors, provide little confidence in the reliability of this finding.

Figure 2 shows coordination performances during the last two sessions of the experiment when subjects were given alcohol plus CO (70 ppm) or alcohol alone. Clearly, there was no systematic tendency for alcohol to potentiate the effects of CO relative to alcohol-along baselines--four subjects showed decreased coordination with alcohol plus CO while the remaining four showed increased coordination.

Finally, Figure 3 summarizes overall coordination performances under each condition of the experiment. Again it is apparent that subjects did not show systematic changes in coordination performance in response to CO; however, all subjects did show deteriorations in coordination following ingestion of alcohol and as demonstrated in the AOV (Table 4), this was found to be highly significant.

Arithmetic Test

Figure 4 presents arithmetic scores of the 24-hour subjects under each concentration of CO and allows a comparison of performances obtained during the 1st and 20th hour of the 24-hour sessions. As may be seen, arithmetic performance did not change with prolonged exposure to CO, regardless of concentration level.

Figure 5 shows, in addition, that alcohol did not systematically potentiate the effect of CO. Three subjects showed a decrease in arithmetic scores but the remainder showed an increase in arithmetic scores when alcohol was combined with CO.

From Figure 6 and from the AOV (Table 4), alcohol as a treatment variable had little effect on ability to solve arithmetic problems, at least at this blood alcohol level.

Inspection Test

Mean and individual inspection scores of the 24-hour subjects after the 1st and after the 20th hour of CO exposure are shown in Figure 7. Only one slight but systematic trend is apparent. Under 70 ppm CO, all four subjects showed decreases in scores after 20 hours of exposure to CO. This finding is in contrast to the slight increase that was noted in coordination after prolonged exposure to 70 ppm CO. As such, and until this finding can be reliably reproduced in future research, it is best viewed as an artifact of the small number of subjects employed in the present study.

Figure 8 shows the inspection scores of each subject in response to alcohol plus CO (70 ppm) and to alcohol alone. Clearly, there is no consistent tendency for alcohol to potentiate the effect of CO on performance of this test since some subjects showed decreased scores while others showed an increase.

Looking at the overall data obtained on the inspection test under each condition of the experiment, summarized in Figure 9 and in the AOV Table, Table 4, it is apparent that the inspection test was not a sensitive measure of responses to either CO or alcohol at these levels.

Time Tests

The AOV F values in Table 4 show that neither time estimations nor reaction time was affected by either CO or alcohol for either sound or light stimuli.

Vigilance Performance

Interpretation of the data obtained from the series of vigilance tests must take into account the adequacy of the test procedures followed. Unfortunately, for the reasons given below, the circumstances under which the vigilance data were collected create serious questions about the validity of the data.

A vigilance task has usually been defined as one in which an individual is required to respond to unpredictable signals in fairly isolated and non-eventful surroundings over long periods of time. For this reason, group-testing

procedures are not conveniently used in the study of vigilance. When subjects work together in groups, especially over extended periods of time, there is the distinct possibility of uncontrolled social interactions which will distort performances. Furthermore, such distortions generally will be in the direction of heightened efficiency, thus complicating efforts to detect behavioral effects of CO or any other toxic substances.

The design of the present study was predicated on the assumption that it would be possible to prohibit interactions among subjects during prolonged group testing of vigilance performance so that valid data could be obtained. Unfortunately, social interaction could not be prevented. Despite efforts to enlist the cooperation of the subjects, including repeated admonishments, a variety of interactions were observed to occur among the subjects including talking, singing, whistling, eye-to-eye contact and even on one occasion, the playing of a game of chess. For these reasons, the data presented below can hardly be viewed as adequately answering the question of whether low levels of CO can influence vigilance performance. Their main value is to indicate the inadequacy of group procedures as a method for studying vigilance performance in reaction to CO.

Figure 10 shows the mean and individual vigilance scores of the 24-hour subjects as each concentration of CO during the first and last 4 hours

of the 24-hour sessions. The only apparent trend is a minor increase in vigilance scores during the last four hours of the 70 ppm CO sessions. Comparisons of the vigilance performance of each subject under alcohol plus CO (70 ppm) versus alcohol alone, shown in Figure 11, do not indicate any trend for alcohol to potentiate the effects of CO. Of the eight subjects, four showed increased and four showed decreased vigilance performance under the CO-plus-alcohol condition.

Figure 12 summarizes performance under each treatment condition of the experiment. As can be seen, there were no differences across CO levels. Figure 12 does indicate substantial decreases in vigilance performance under alcohol, an effect present in every subject. That alcohol will result in disruptions of performance requiring sustained attention is a well-established finding, and in the context of the present study shows that the group testing procedure, despite its inadequacies, was not totally insensitive to the effects of alcohol.

An important characteristic of vigilance performance is that it deteriorates progressively over extended test sessions. Figure 13, which presents scores during each of the four hours shows that this did not occur in the present experiment. If there is any trend, it is that scores were lowest during the second hour and gradually increased to a maximum during the fourth hour. (In the case of the alcohol condition this pattern may have been caused by the decrease in blood alcohol level with time.) The

genera. finding that vigilance performance did not deteriorate during the tests bears out the aforementioned conclusions concerning the inadequate sensitivity of the procedures. It is likely that interactions ensuing between the subjects during testing permitted them to maintain a high level of alertness during the 4-hour course of the tests. Any subtle behavioral effects of CO on vigilance would be effectively masked under these conditions.

DISCUSSION

The purpose of these two studies was to test the hypotheses that a 24-hour exposure to low levels of CO would have deleterious effects on behavior and that alcohol would potentiate such effects. The data obtained from tests of coordination, arithmetic ability, inspection, manual dexterity, time estimations and vigilance did not provide evidence to substantiate either of these hypotheses.

The lack of CO effect was not unexpected as previous studies in this laboratory for acute exposure have shown no effect of CO on time estimations,[1] arithmetic, inspection or coordination.[2]

The experimental design did not include replicates of each exposure combination and thus CO-alcohol interactions could not be calculated. From the mean scores, however, there was no evident synergistic effect of the two. Negative findings place a special burden on the researcher obtaining such

findings. They may reflect the fact that the variable in question indeed has no influence. But it also is possible that negative findings reflect inadequacies of the experimental method, such as sample size, insensitive procedures, and the lack of control of extraneous variables.

Investigators working in another laboratory have reported performance decrements as a consequence of exposure to low levels of CO.[3,4] The present results, on the other hand, as well as those of several other prior investigations have not indicated such effects.[1,5,6,7] The issue is whether these differences in findings should be interpreted to mean that CO has no behavioral effects, or whether some procedures are insensitive to real effects.

There are at least three aspects of the behavioral testing procedures of this work which may have contributed to negative results. An obvious factor concerns the procedure of testing groups of subjects rather than individual subjects. It may be more than coincidence that Beard, who has obtained positive results, has characteristically studied subjects one at a time. If low concentrations of CO do have behavioral effects, those effects seem most likely to appear under conditions of isolation. Testing in groups undoubtedly created states of alertness and arousal which may have effectively masked subtle cognitive and perceptual-motor effects of CO. However, a test of that hypothesis conducted using individual

subjects in an experimental design identical to Beard's showed no deleterious effects of CO.[1] Group interaction then does not appear to be an applicable explanation in this case.

A second factor possibly contributing to error and insensitivity involves social relationships which may develop between subjects and the research staff. In some respects the procedures in this laboratory are informal and may be characterized as treating subjects more as collaborators in the research endeavor than as subjects. Even though approach may not be inappropriate for strictly physiological or medical work, it is a potential source of serious experimental error in behavioral work. It is advisable, if not essential, to develop more formal procedures which will reduce as much as possible social interactions between subjects and the research staff. These procedures must begin at the point that the subject is enlisted into the experiment, and should be followed strictly at every point along the way. Only by imposing this sort of rigor will it be possible to observe behavioral reactions to CO uncontaminated by other variables.

Finally, and quite apart from the question of experimental control, is the question of test sensitivity. There are no simple rules that can be applied to determine which behavioral measure stands the best chance of revealing changes in response to CO, and there was justification for using the tests of the present experiment. There is reason to believe that highly

skilled performances will be resistant to disruption by toxic agents, and for this reason training before testing may have worked against the possibility of detecting CO effects. In any case, to show subtle behavioral effects, tests at least potentially sensitive to many variables must be used. The present study showed no decrements on tests of inspection, arithmetic ability, or time estimations under the influence of alcohol. A test which is insensitive to alcohol could probably not be expected to be sensitive to CO. However, these are the tests which other investigators have shown to be affected by CO and, therefore, they were included in this research.

SUMMARY

The purpose of these two studies was to test the hypothesis that a 24-hour exposure to low levels of CO would have deleterious effects on behavior and that alcohol would potentiate such effects. The data obtained from both studies for tests of coordination, arithmetic, inspection, manual dexterity, time estimation, and vigilance did not provide evidence to substantiate either of these hypotheses. The only positive result was alcohol adversely affects eye-hand coordination.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the technical assistance of S. Graff, K. Donohoo, D. Fleischfresser and K. Kujawski. They also thank Miss Susan Kamke for her help in preparation of this manuscript.

REFERENCES

1. Stewart, R.D., Newton, P.E., Hosko, M.J. and Peterson, J.E.. "The Effect of Carbon Monoxide on Time Perception", (a) CRC Report No. CRC APRAC CAPM-3-68, MCOW-ENVM-CO-72-1, (b) Arch. Environ. Health: 27:155-160, 1973.

2. Stewart, R.D., Newton, P.E., "The Effect of Carbon Monoxide on Eye-Hand Coordination, Manual Dexterity and Mathematical Abilities", unpublished report.

3. Beard, R.R., Wertheim, G.A., "Behavioral Impairment Associated with Small Doses of Carbon Monoxide", Am. J. Public Health 57:2012-2022, 1967.

4. Beard, R.R., Wertheim, G.A., "Behavioral Manifestations of Carbon Monoxide Absorption", read before the 16th International Congress on Occupational Health, Tokyo, 1969.

5. Stewart, R.D., et al, "Experimental Human Exposure to Carbon Monoxide", Arch. Environ. Health, 21:154-160, 1970.

6. O'Donnell, R.D., et al, "Low Level Carbon Monoxide Exposure and Human Psychomotor Performance", Toxicol. Appl. Pharmacol., 18:593-602, 1971.

7. O'Donnell, R.D., Cherkos, P., Theodore, J., "Effect of Carbon Monoxide Exposure on Human Sleep and Psychomotor Performance", J. Appl. Physiol., 31:513-518, 1971.

TABLE 1

SUBJECT BLOOD ALCOHOL LEVEL AND PERCENT CARBOXYHEMOGLOBIN SATURATION IMMEDIATELY FOLLOWING TESTING SESSION - STUDY A

	Exp. 1		Exp. 2		Exp. 3		Exp. 4	
SUBJECT	Blood Alcohol mg. %	COHb	Blood Alcohol mg. %	COHb	Blood Alcohol mg. %	COHb	Blood Alcohol mg. %	COHb
R.S.	--	0.4	--	15.9	48.2	0.6	50.7	15.2
F.G.	--	0.3	--	14.5	36.6	0.7	52.7	13.6
D.T.	--	1.0	--	N.A.	69.9	1.6	74.0	15.4
T.K.	--	1.4	--	15.2	45.6	0.6	82.0	13.8
K.H.	--	1.0	--	N.A.	< .5	0.5	< .5	13.9
T.M.	--	0.9	--	14.9	46.8	0.5	42.0	13.9

TABLE 2

ANALYSIS OF VARIANCE FOR THE EFFECT OF CARBON MONOXIDE AND ETHYL ALCOHOL ON BEHAVIORAL TESTS - STUDY A

TEST	EFFECT	df	F Ratio
Collar and Pin	Alcohol	1	15.75
	CO	1	121.00**
Coordination	Alcohol	1	60.49*
	CO	1	1.49
Arithmetic	Alcohol	1	1.67
	CO	1	0.69
Hand Steadiness	Alcohol	1	1.47
	CO	1	0.01

** Significant at $p < .01$

* Significant at $p < .05$

TABLE 3

SUBJECT BLOOD ALCOHOL LEVELS AND PERCENT CARBOXYHEMOGLOBIN SATURATION IMMEDIATELY PRIOR TO TESTING SESSION - STUDY B

	Exp. 1		Exp. 2	
SUBJECT	Blood Alcohol mg. %	COHb	Blood Alcohol mg. %	COHb
J.H.	45.3	8.7	27.9	1.5
J.R.	58.8	7.8	56.3	0.9
R.S.	58.2	9.1	42.3	0.5
R.C.	59.2	9.3	37.4	0.21
B.F.	54.3	9.5	54.2	0.5
B.G.	58.8	8.7	48.4	0.4
S.P.	59.9	8.4	53.7	0.4
J.W.	60.5	9.1	51.1	1.0

TABLE 4

ANALYSIS OF VARIANCE FOR THE EFFECT OF CARBON MONOXIDE AND ETHYL ALCOHOL ON BEHAVIORAL TESTS - STUDY B

TEST	EFFECT	df	F RATIO
Marquette:			
Sound Stimulus:			
Estimate/Stimulus	Alcohol	1	3.23
	CO	1	0.36
|Estimate-Stimulus|	Alcohol	1	4.25
	CO	1	0.34
Reaction Time	Alcohol	1	0.04
	CO	1	0.13
Light Stimulus:			
Estimate/Stimulus	Alcohol	1	15.98
	CO	1	35.96
|Estimate-Stimulus|	Alcohol	1	26.10
	CO	1	31.31
Reaction Time	Alcohol	1	1.39
	CO	1	1.00
10 Second Estimations	Alcohol	1	0.58
	CO	1	0.00
30 Second Estimations	Alcohol	1	0.01
	CO	1	0.70
Arithmetic:	Alcohol	1	0.72
	CO	1	0.01
Coordination:	Alcohol	1	718.67*
	CO	1	8.53
Inspection:	Alcohol	1	0.87
	CO		0.08

*Significant at $p < .001$

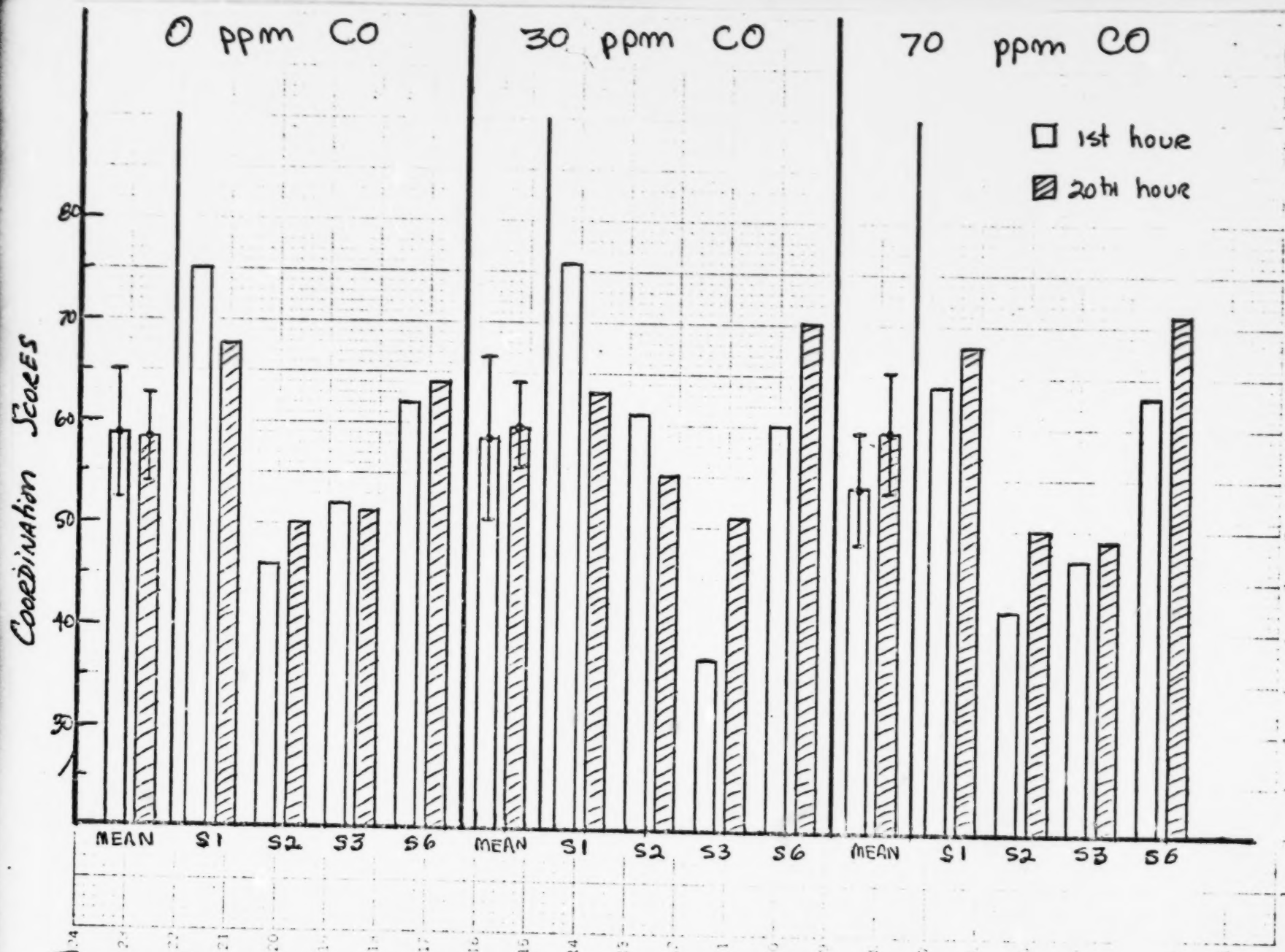


Fig. 1. Coordination scores of 24-hour subjects under each level of CO showing individual and mean performances during the 1st and 20th hour of 24-hour sessions. MEAN VALUES ARE EXPRESSED AS MEAN ± the STANDARD ERROR.

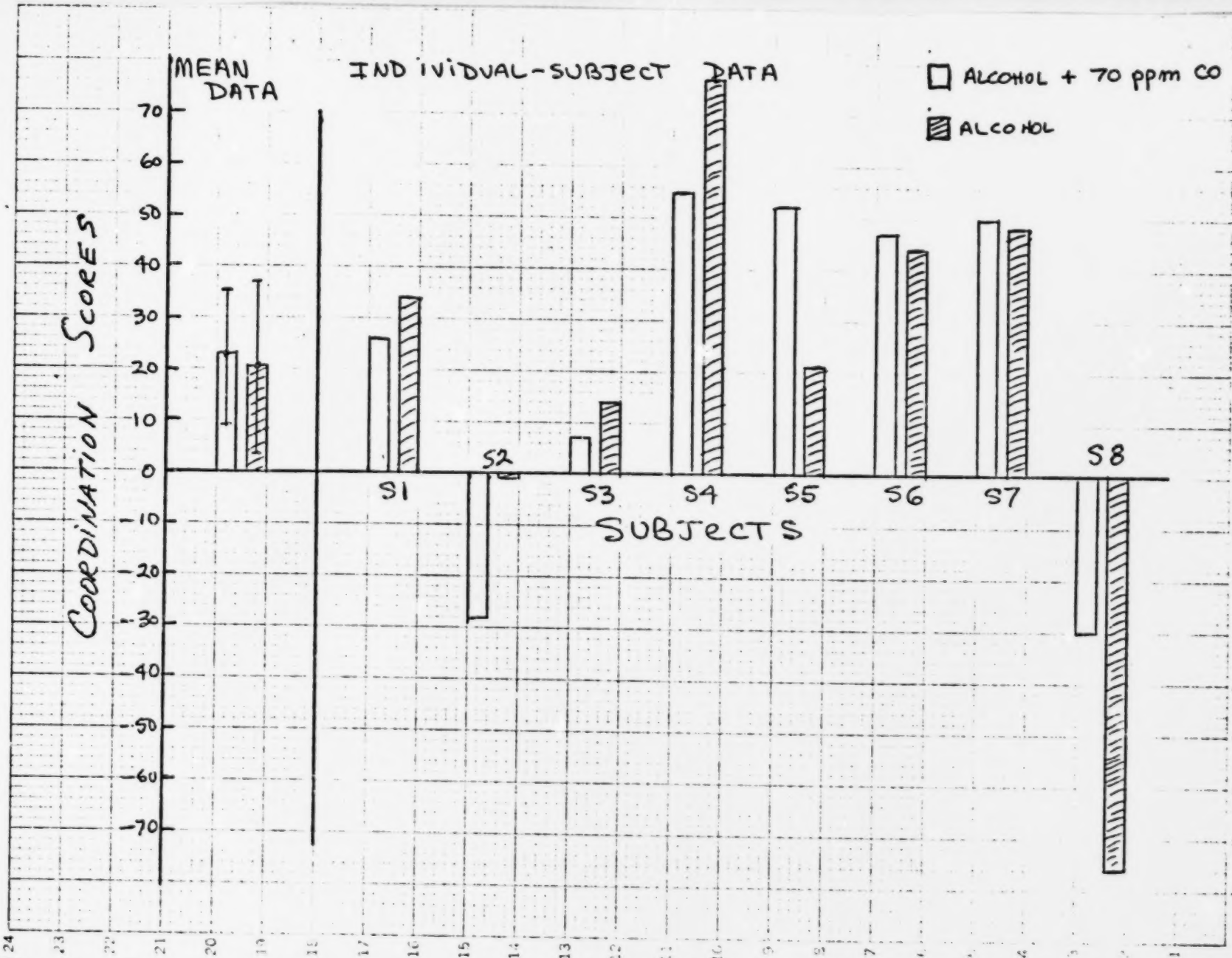


FIG. 2 COORDINATION SCORES of EACH SUBJECT UNDER the conditions of ALCOHOL plus CO (70 ppm) versus ALCOHOL ALONE. MEAN VALUES ARE expressed AS MEAN ± the STANDARD error.

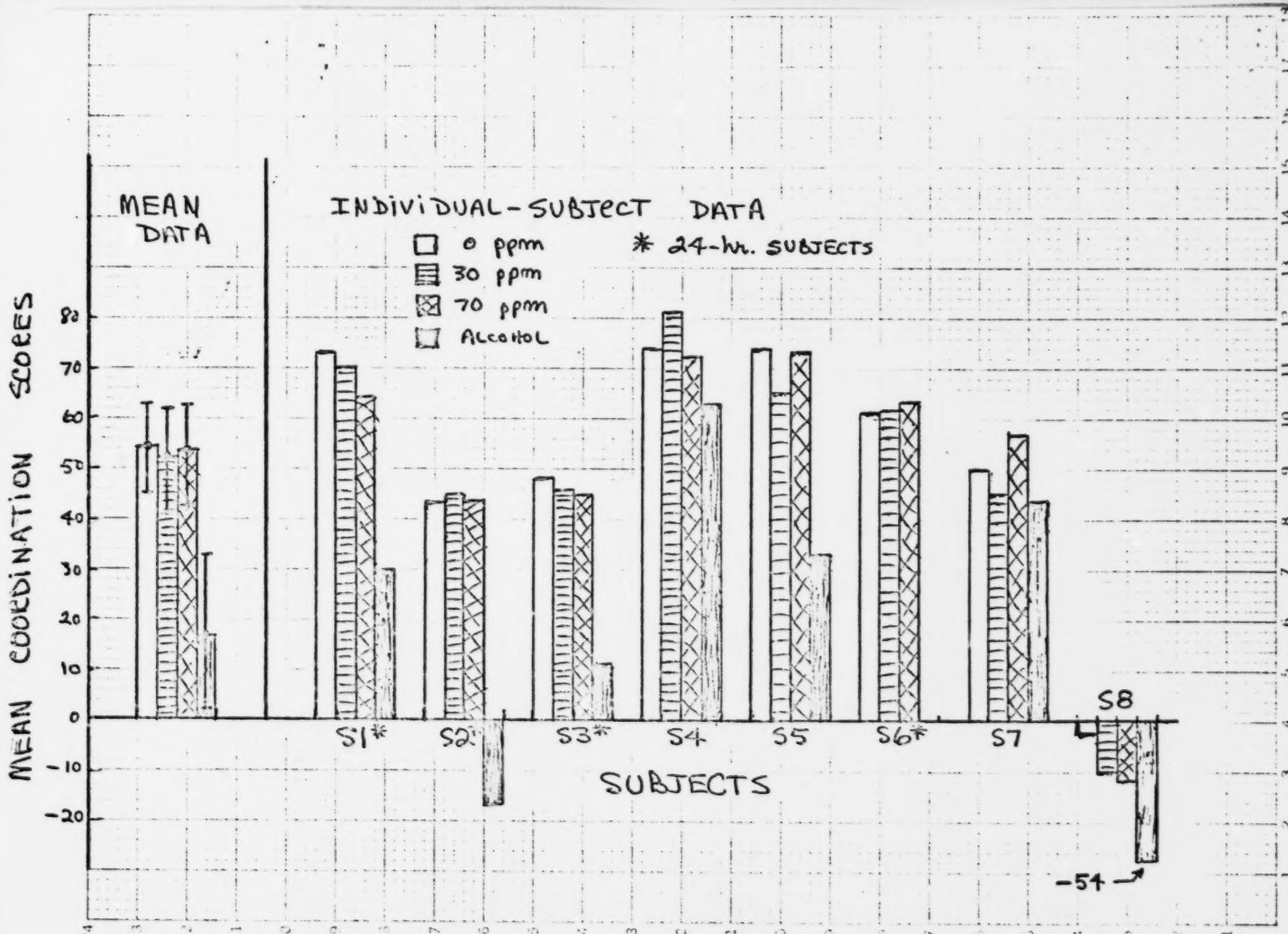


FIG. 3. MEAN COORDINATION SCORES of EACH SUBJECT UNDER EACH condition OF THE EXPERIMENT. ALSO SHOWN ARE THE MEANS AND STANDARD ERRORS FOR THE COMBINED SUBJECTS

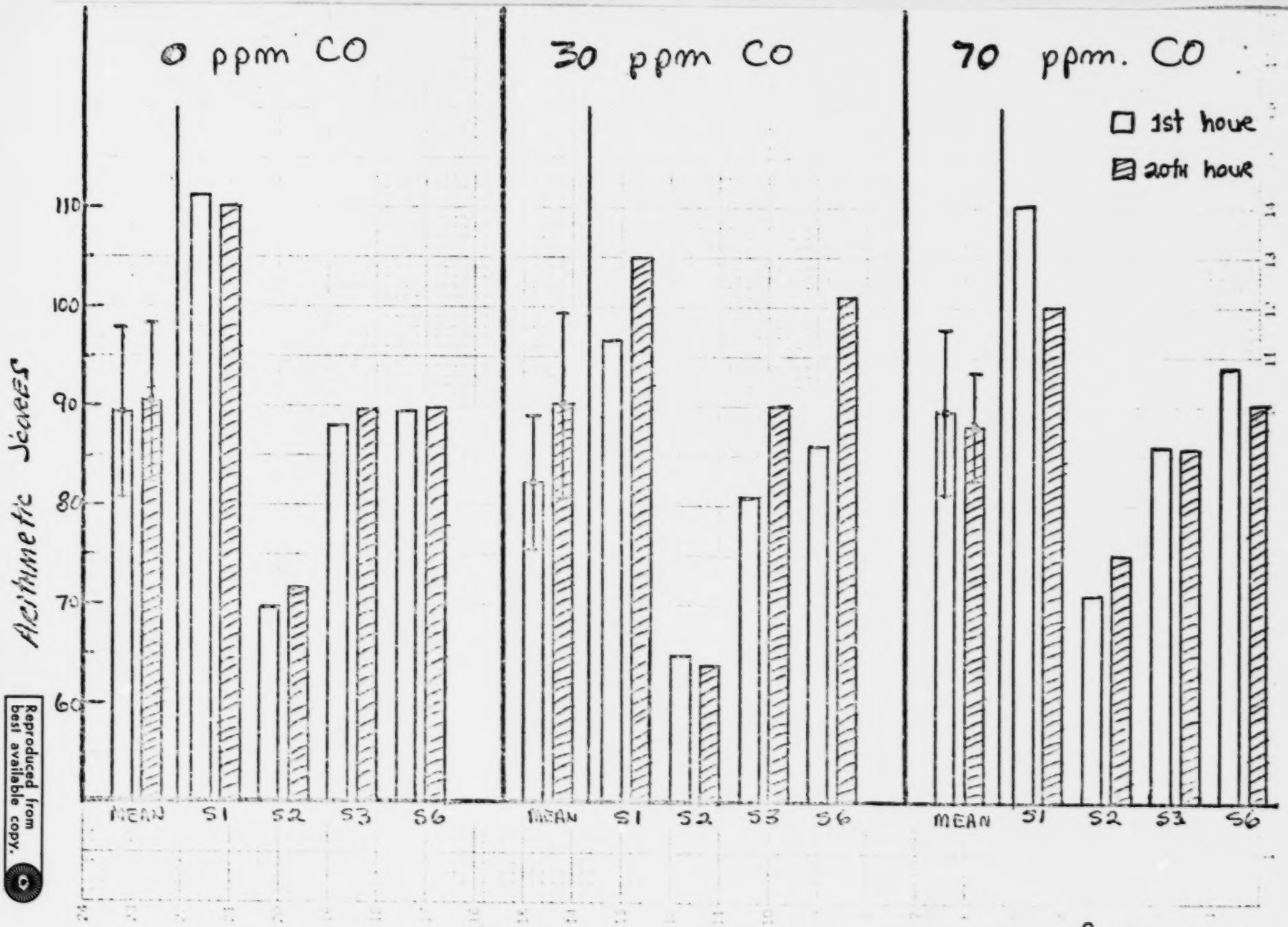


FIG. 4. ARITHMETIC SCORES of 24-HOUR SUBJECTS UNDER EACH LEVEL of CO SHOWING INDIVIDUAL AND MEAN PERFORMANCES DURING THE 1st AND 20TH HOUR OF 24-HOUR SESSIONS. MEAN VALUES ARE EXPRESSED AS MEAN ± the STANDARD ERROR.

Reproduced from best available copy.

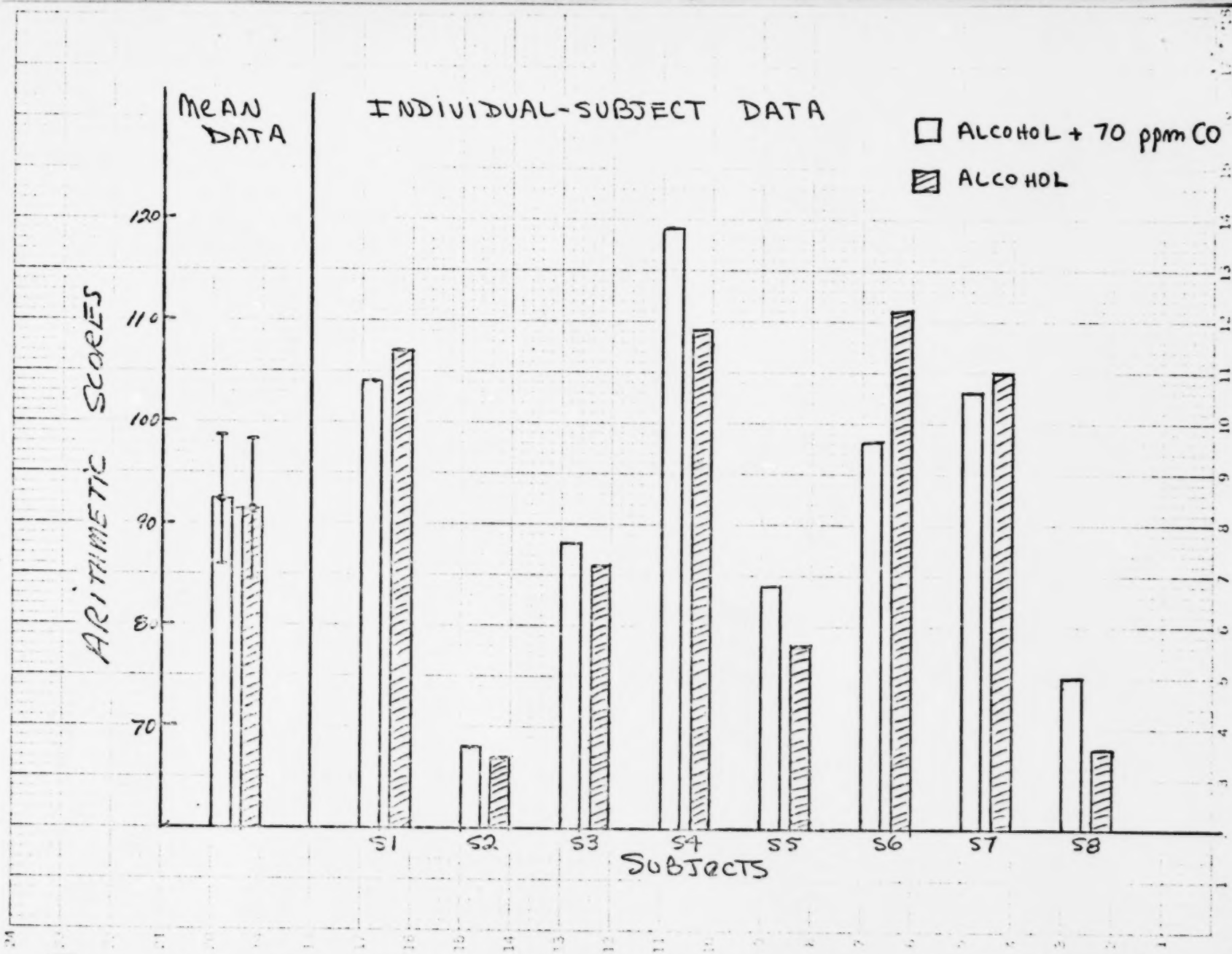


Fig 5. ARITHMETIC SCORES of EACH SUBJECT UNDER the conditions of ALCOHOL PLUS CO (70 ppm) versus ALCOHOL ALONE. MEAN VALUES ARE EXPRESSED AS MEAN ± the STANDARD error.

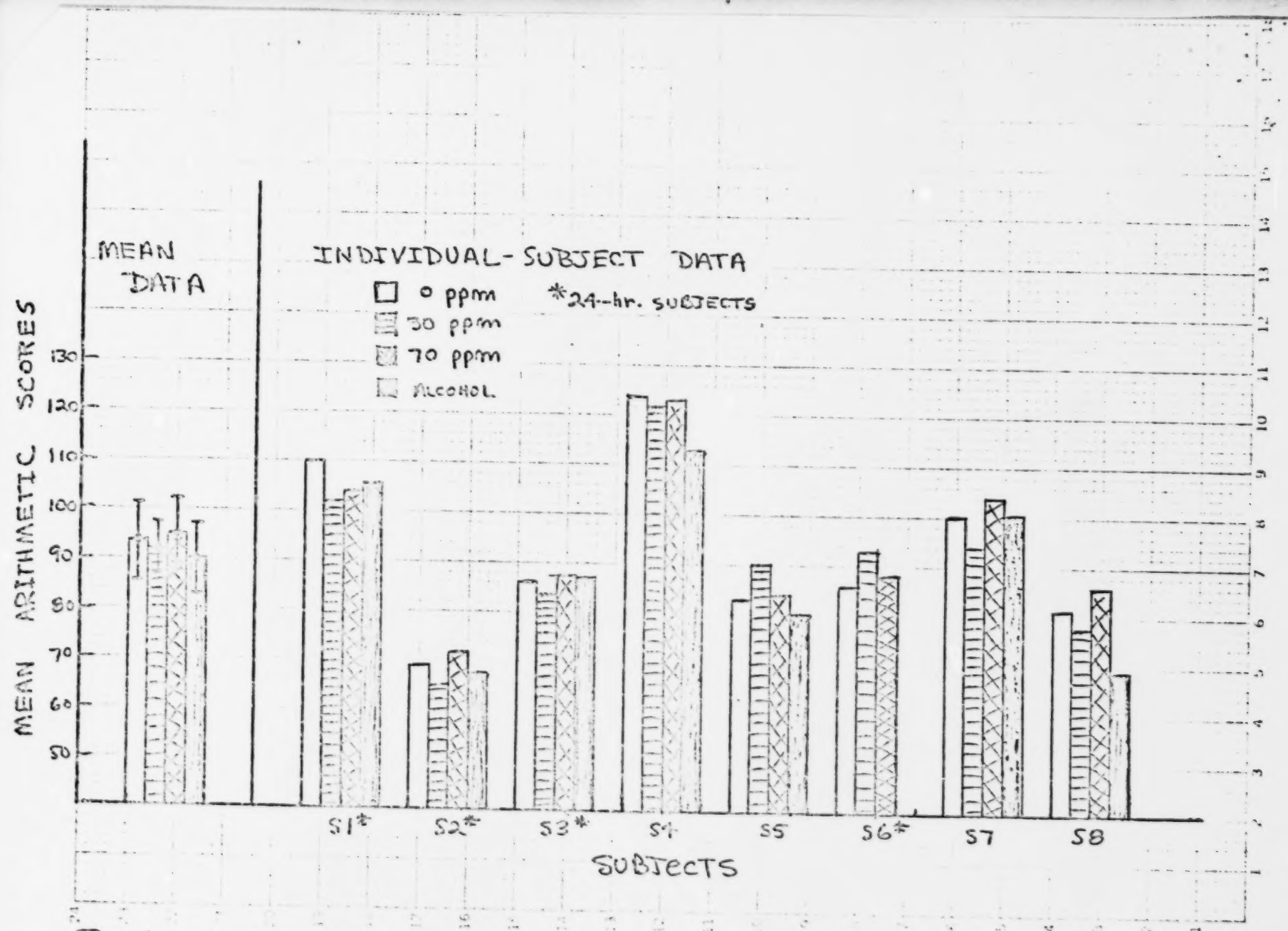


FIG. 6. MEAN ARITHMETIC SCORES OF EACH SUBJECT UNDER EACH EXPERIMENTAL CONDITION. ALSO SHOWN ARE THE MEANS AND STANDARD ERRORS FOR THE COMBINED SUBJECTS.

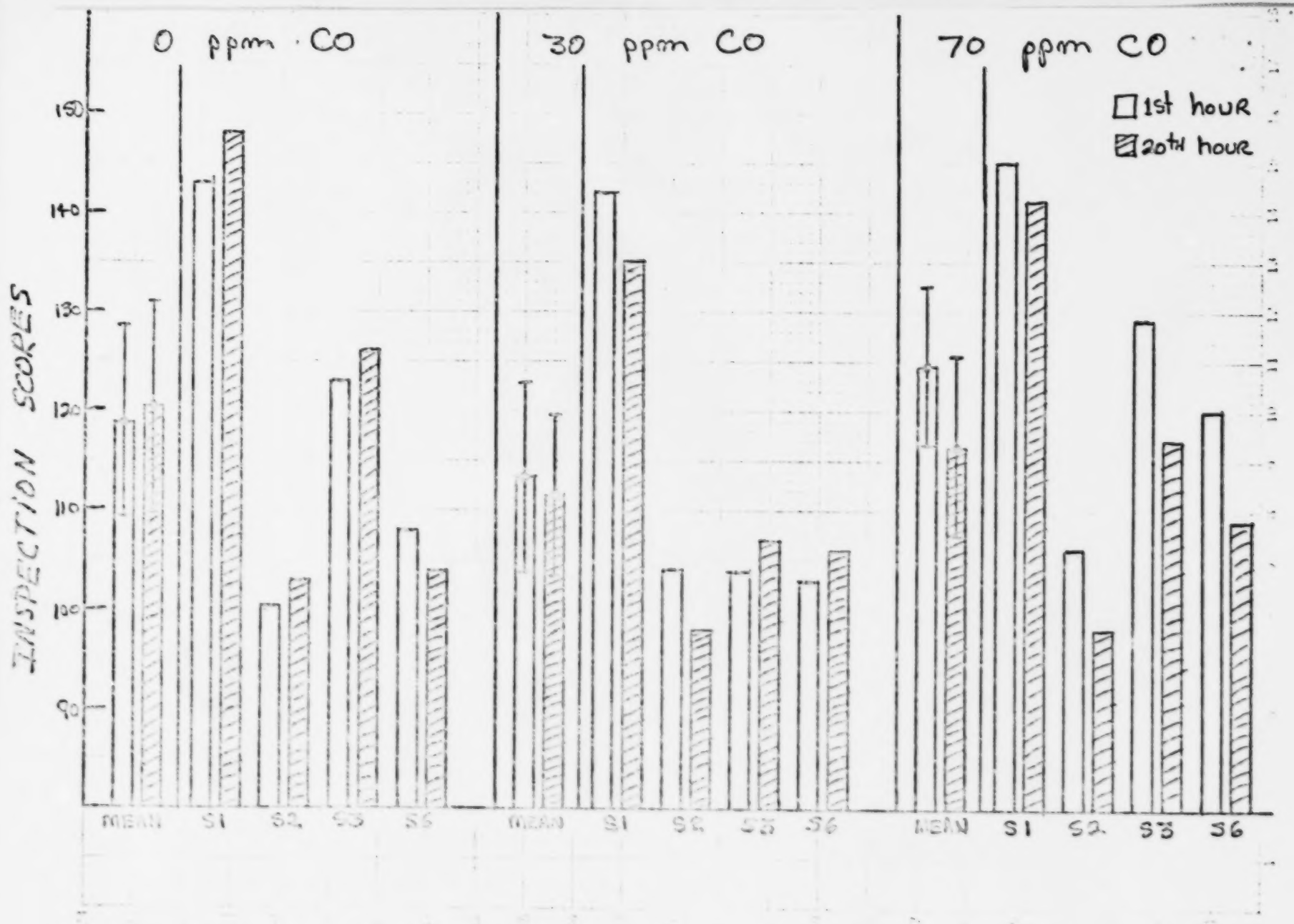
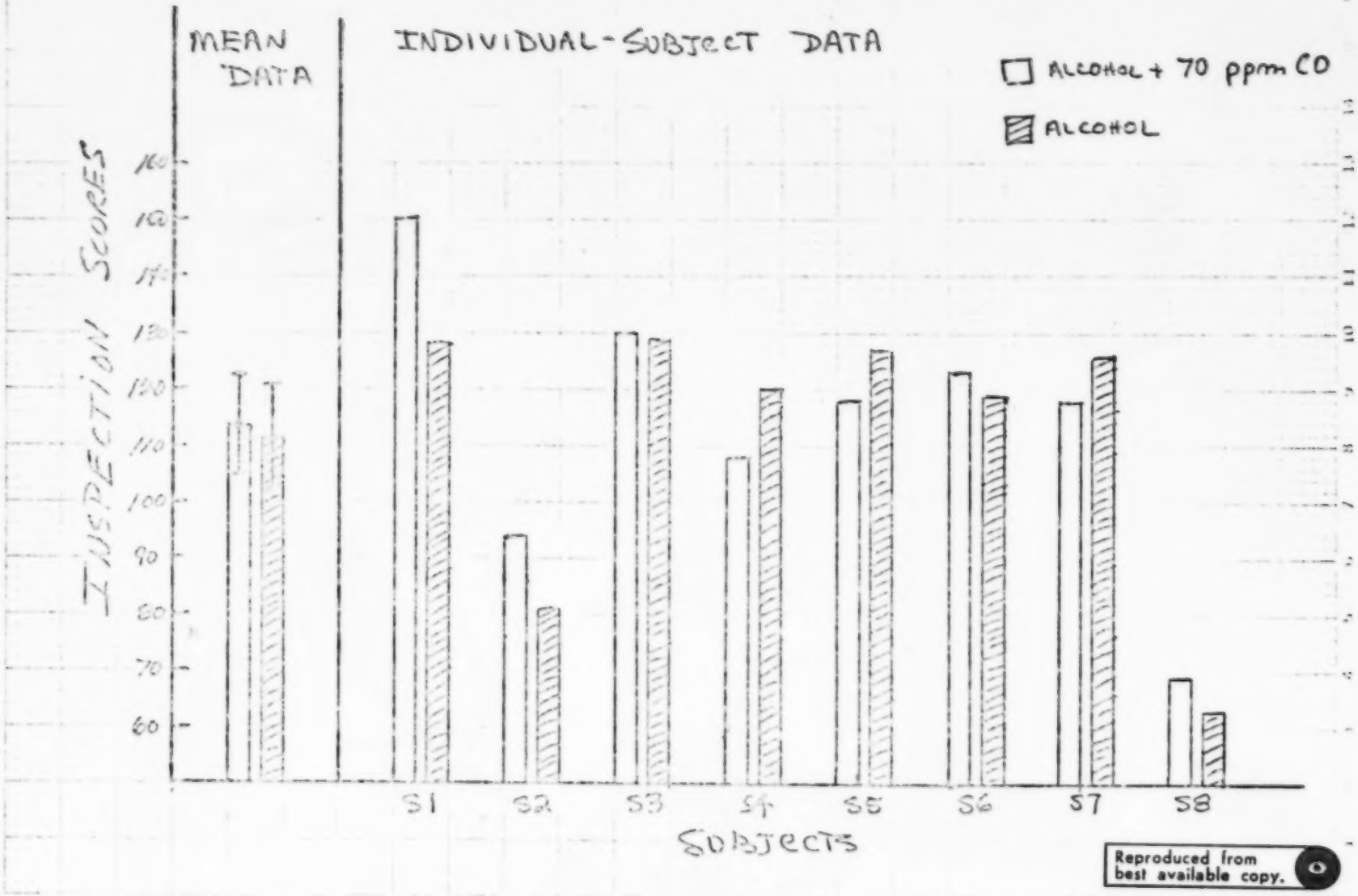


Fig 7. Inspection Scores of 24-hour subjects under each level of CO showing individual and mean performances During the 1st and 20th Hour of 24-hour sessions. Mean values are expressed as mean ± the Standard error.



Reproduced from best available copy.

FIG. 8 Inspection scores of each subject under the conditions of alcohol plus CO (70 ppm) versus alcohol alone. Mean values are expressed as mean ± the standard error.

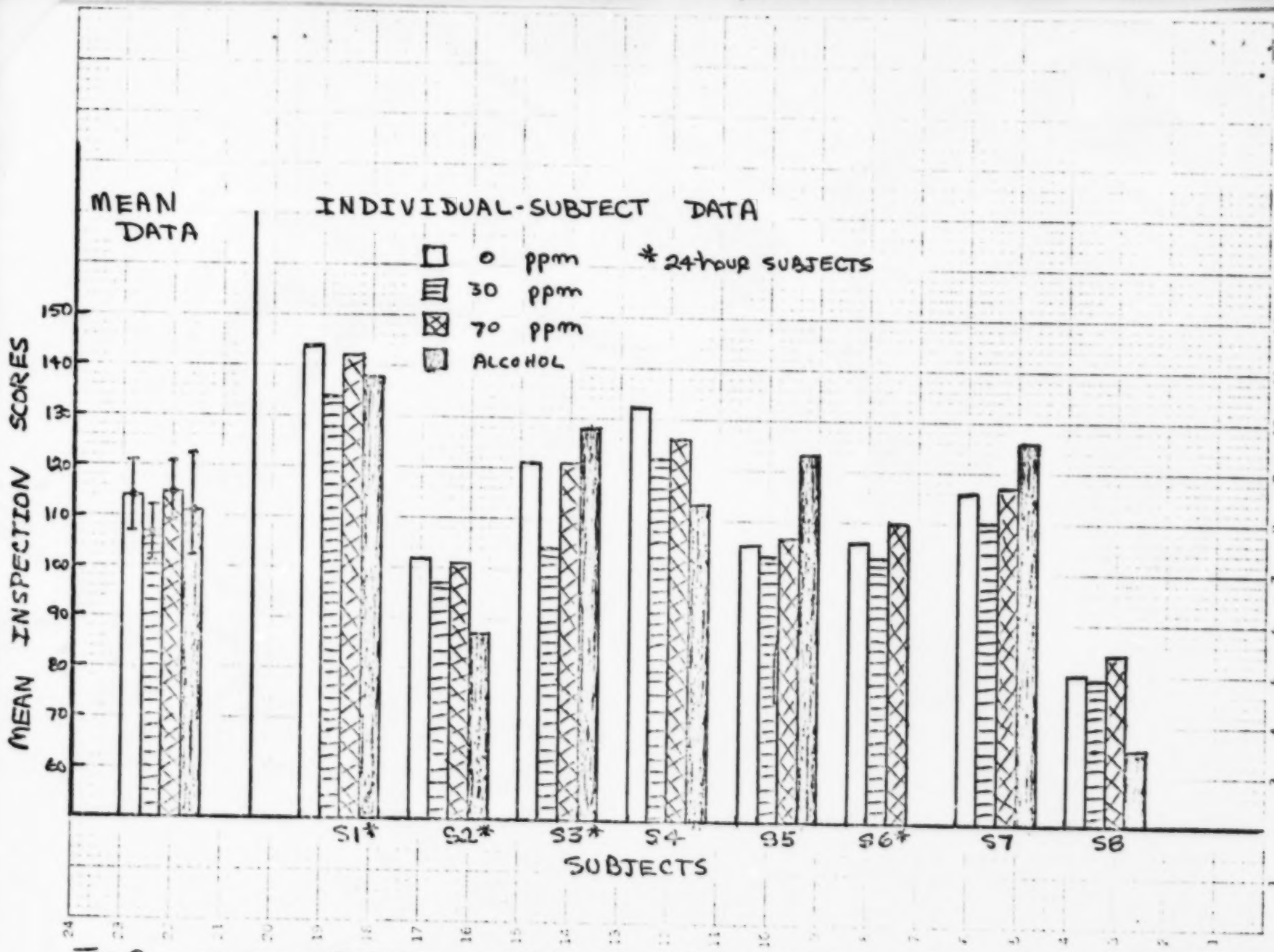


Fig 9 MEAN INSPECTION SCORES OF EACH SUBJECT UNDER EACH EXPERIMENTAL CONDITION. ALSO SHOWN ARE THE MEANS AND STANDARD ERRORS FOR THE COMBINED SUBJECTS.

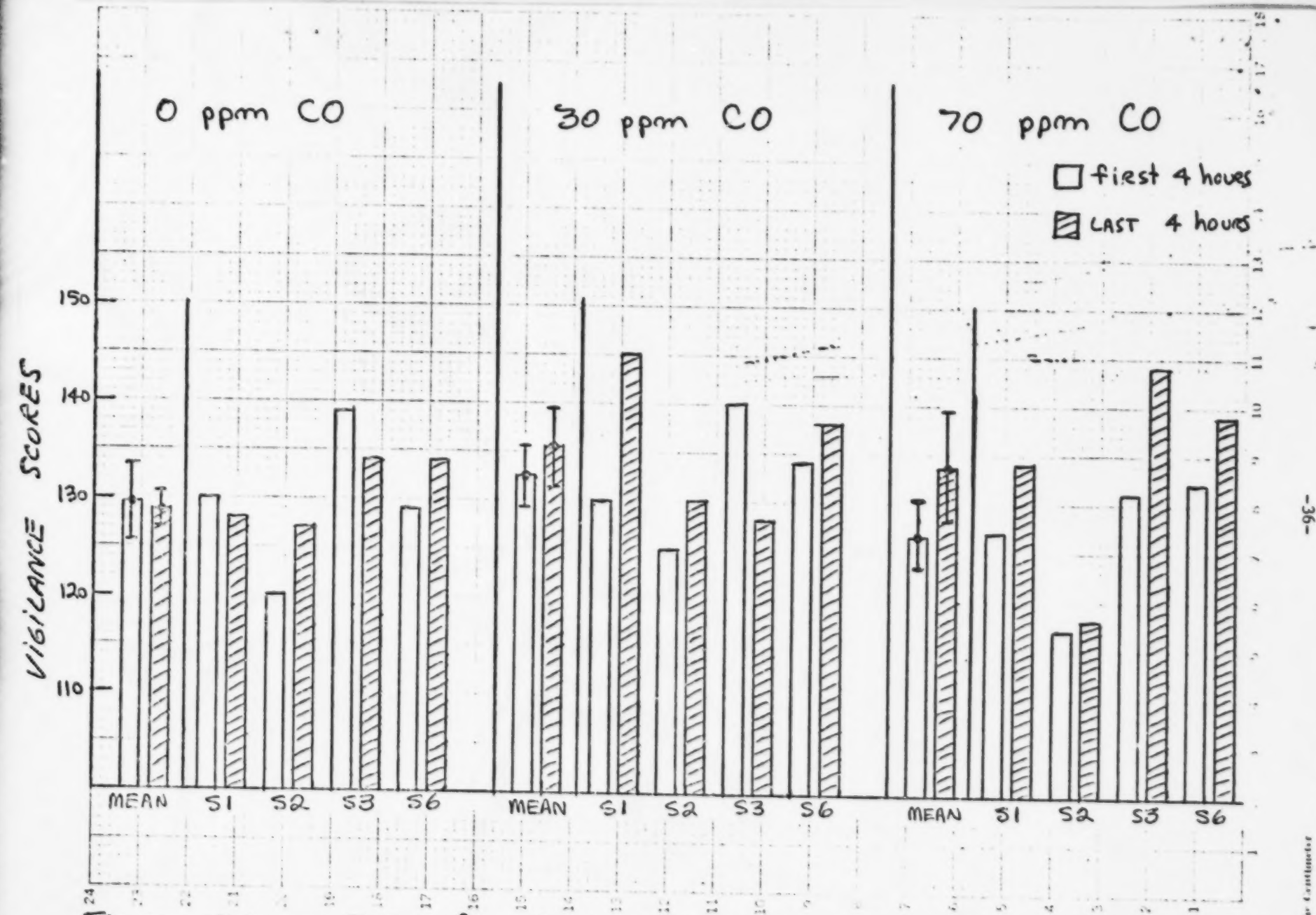


FIG. 10. VIGILANCE SCORES OF 24-HOUR SUBJECTS UNDER EACH LEVEL OF CO SHOWING INDIVIDUAL AND MEAN PERFORMANCES DURING THE FIRST AND LAST 4 HOURS OF THE 24-HOUR SESSIONS. MEAN VALUES ARE EXPRESSED AS MEAN ± THE STANDARD ERROR.

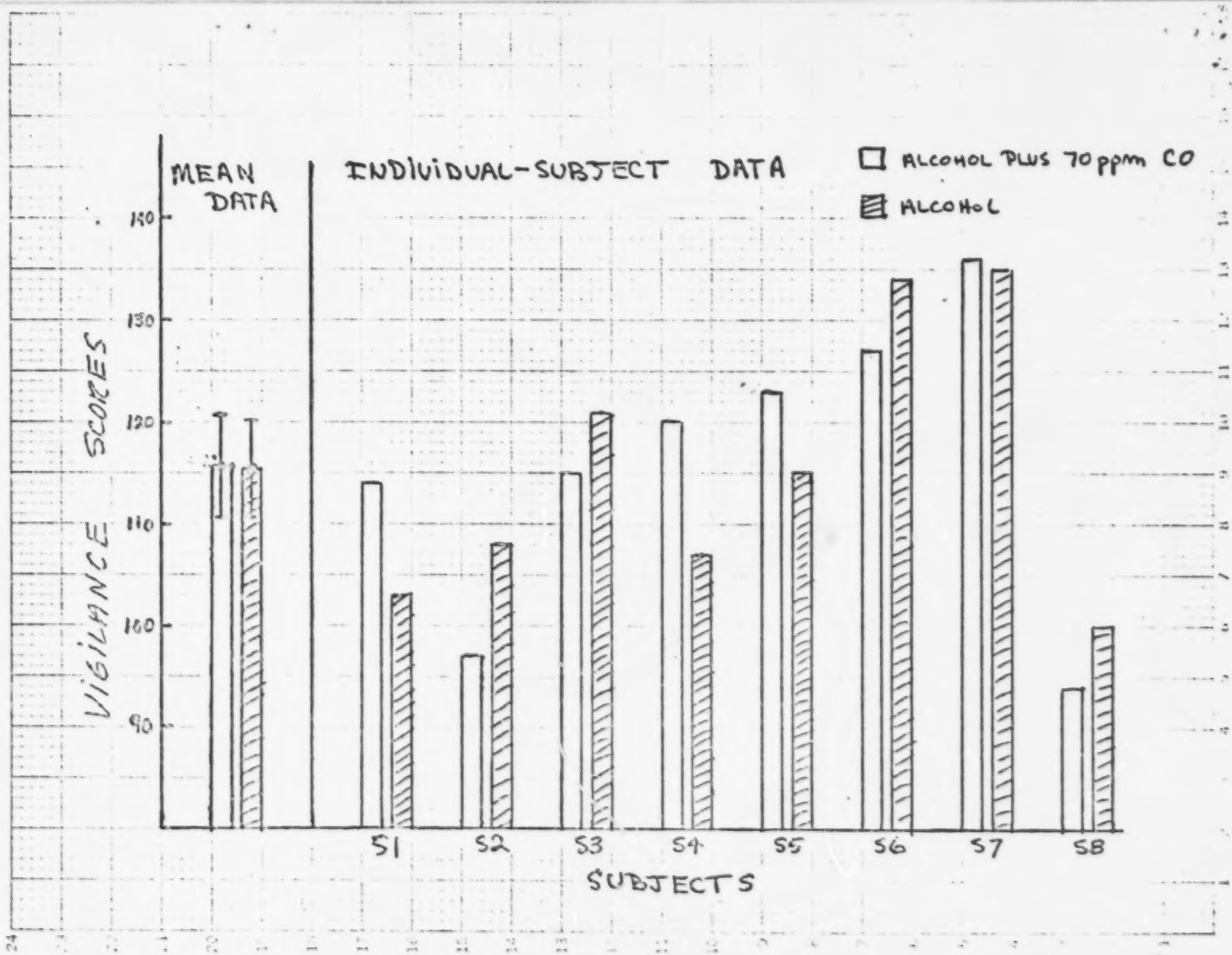


FIG. 11. VIGILANCE SCORES of EACH SUBJECT under the conditions of ALCOHOL PLUS CO (70 ppm) versus ALCOHOL ALONE. MEAN VALUES ARE EXPRESSED AS MEAN ± the STANDARD ERROR.

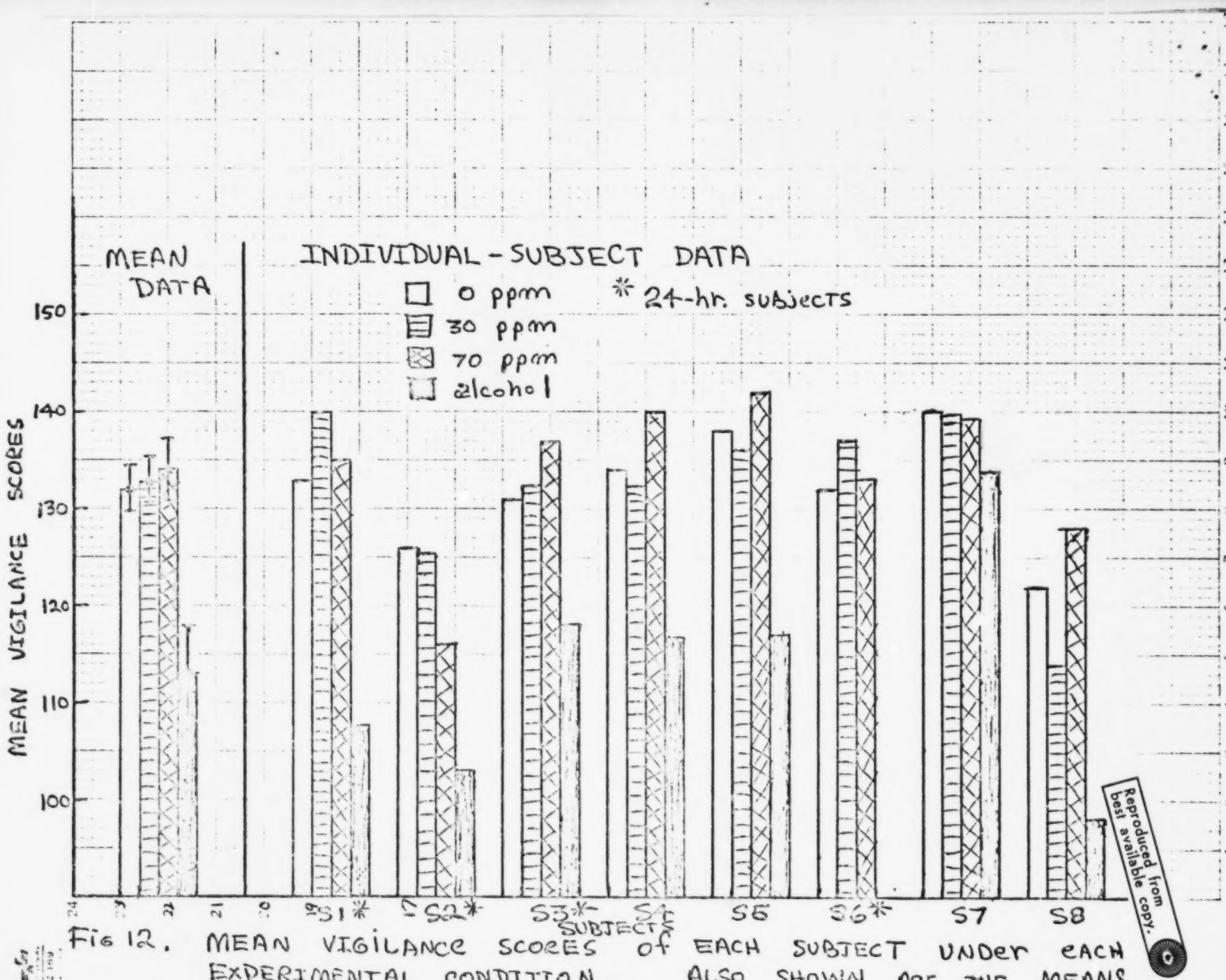


Fig 12. MEAN VIGILANCE SCORES of EACH SUBJECT UNDER EACH EXPERIMENTAL CONDITION. ALSO SHOWN ARE THE MEANS AND STANDARD ERRORS FOR THE COMBINED SUBJECTS.

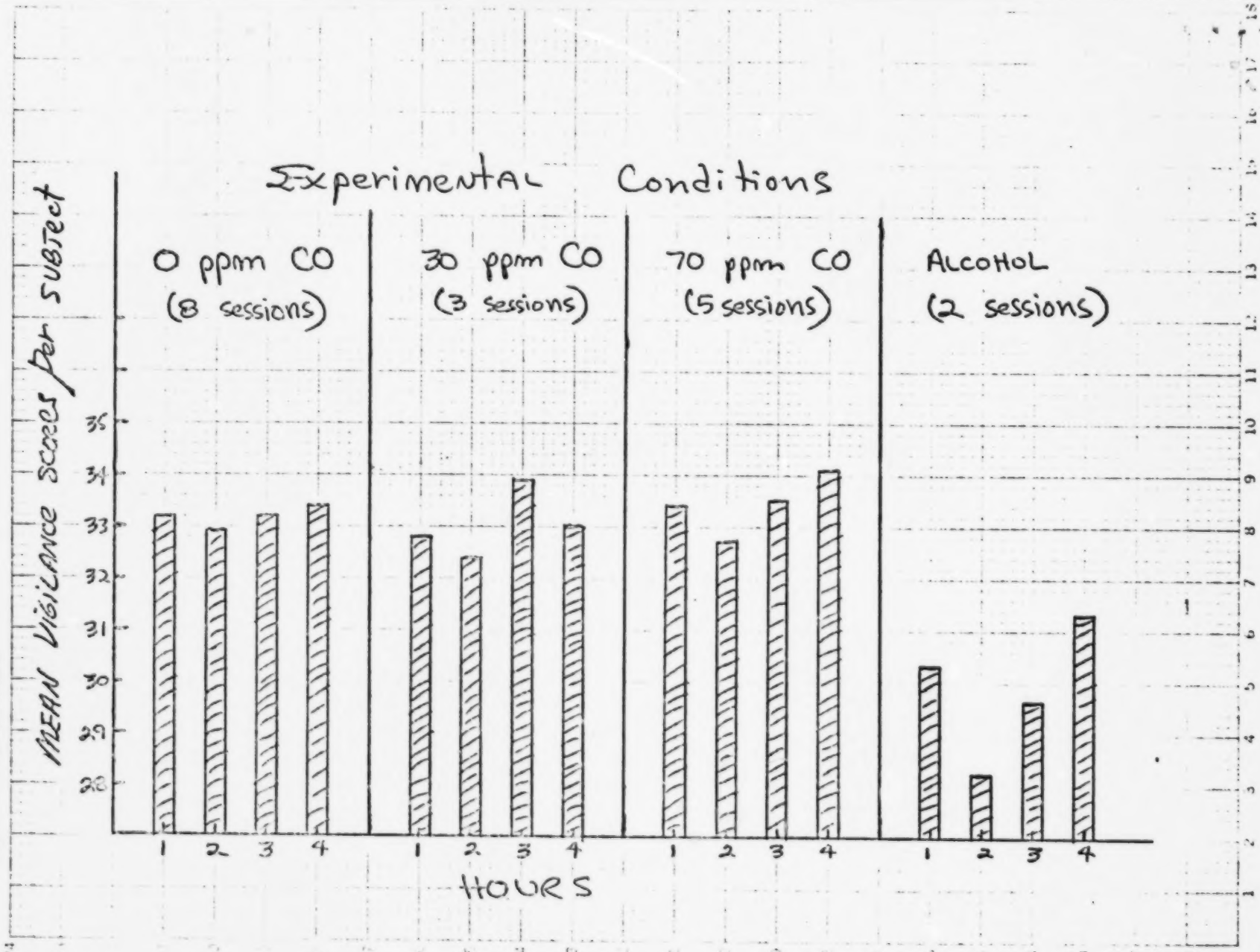


Fig. 13. Mean Vigilance Scores per subject for each hour of the 4-hour vigilance test under each condition of the experiment. A perfect score would be 40.

Reproduced from best available copy.